The Science of Seat Cushions

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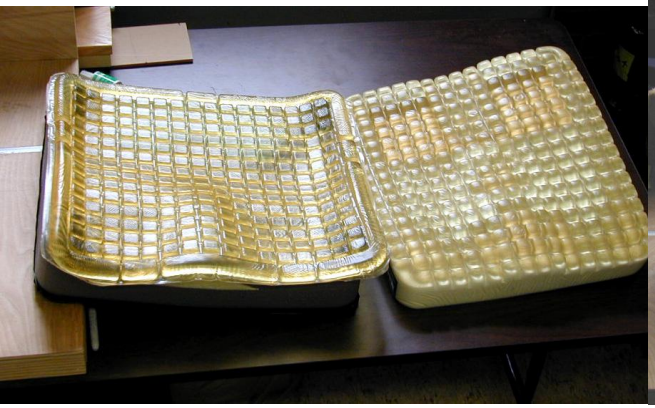
SUNRISE MEDICAL®

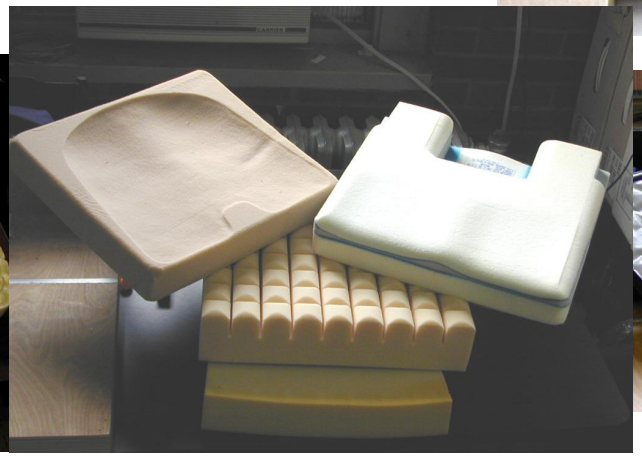
Important characteristics of wheelchair cushions

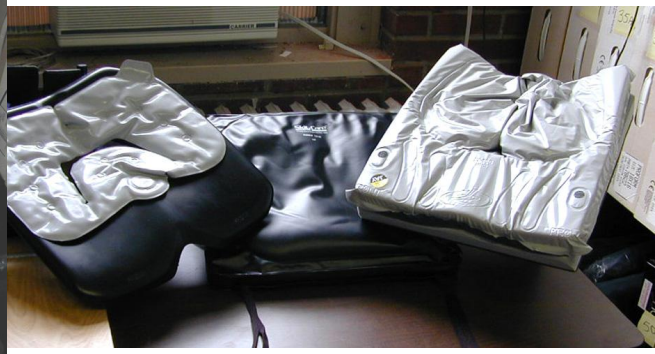
- Mechanical Properties
  - Load deflection
  - Recovery
  - Impact Damping
  - Loaded contour depth
  - Frictional properties
- Load redistribution
  - Envelopment
  - Off-loading and redirection
  - Interface Pressure Distribution
- Heat & Water Vapor Dissipation

Cushion Materials: Material combinations dominate

- Foam/flexible matrix: GeoMatt, Supracore, Fundamental
- Foam & Elastomer/gel: Southwest Technologies, Action
- Foam & Viscoelastic Foam:Maxus, Infinity, Ultimate
- Foam & Viscous Fluid: Jay, Cloud, Skil-Care
- Air: Roho, Star, BBD
- Air & Foam: Varilite, Nexus







Mechanical Properties

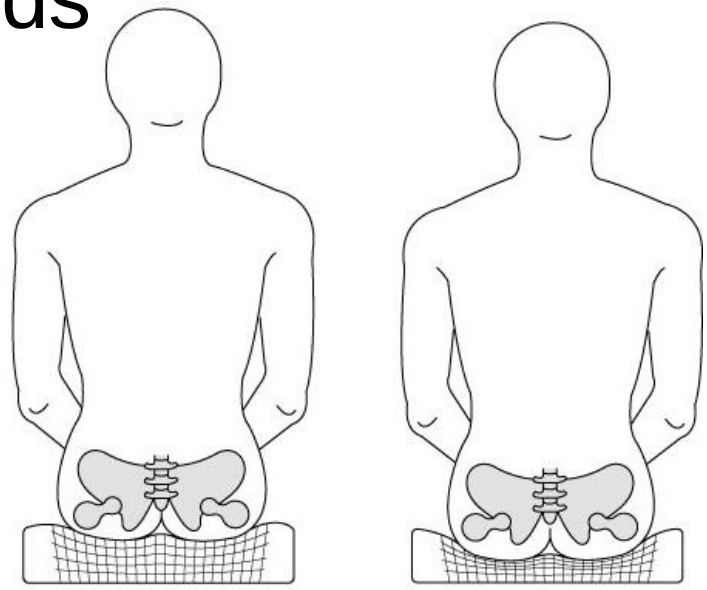
- Different materials accommodate body load in different manners
  - foam and air: compression
  - gel and viscous fluid: displacement
  - cover (bladder and/or fabric): tension

Mechanical Properties: Load deflection

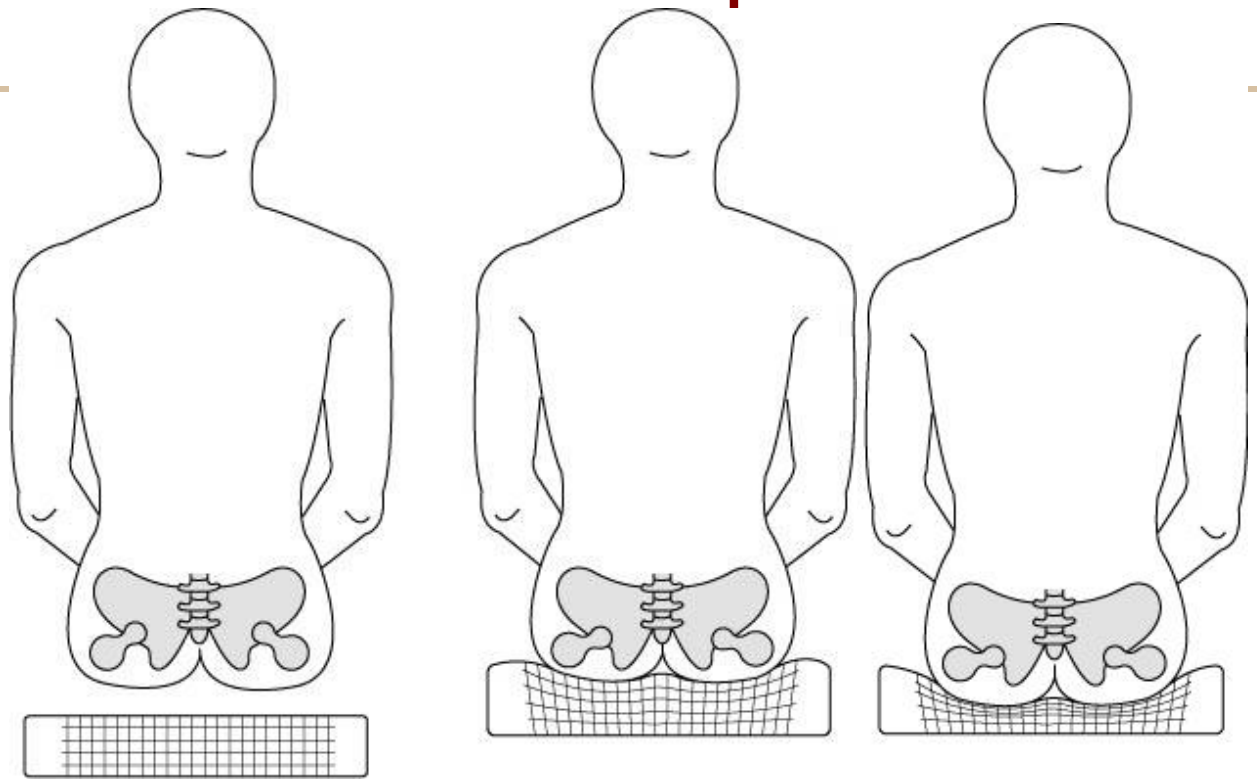
- Stiffness is a measure of deflection under a given load
  - Foam: Indentation Force Deflection
  - Elastomers and gel: durometer
  - Viscous Fluid: viscosity & bladder volume
  - Air: Internal air pressure and bladder stiffness

Load Deflection

- The trick is finding the proper stiffness
  - Too stiff → high loads 2º to poor deflection
  - Too soft → bottoming-out 2º to over-deflection
- Material combinations used to accommodate various needs

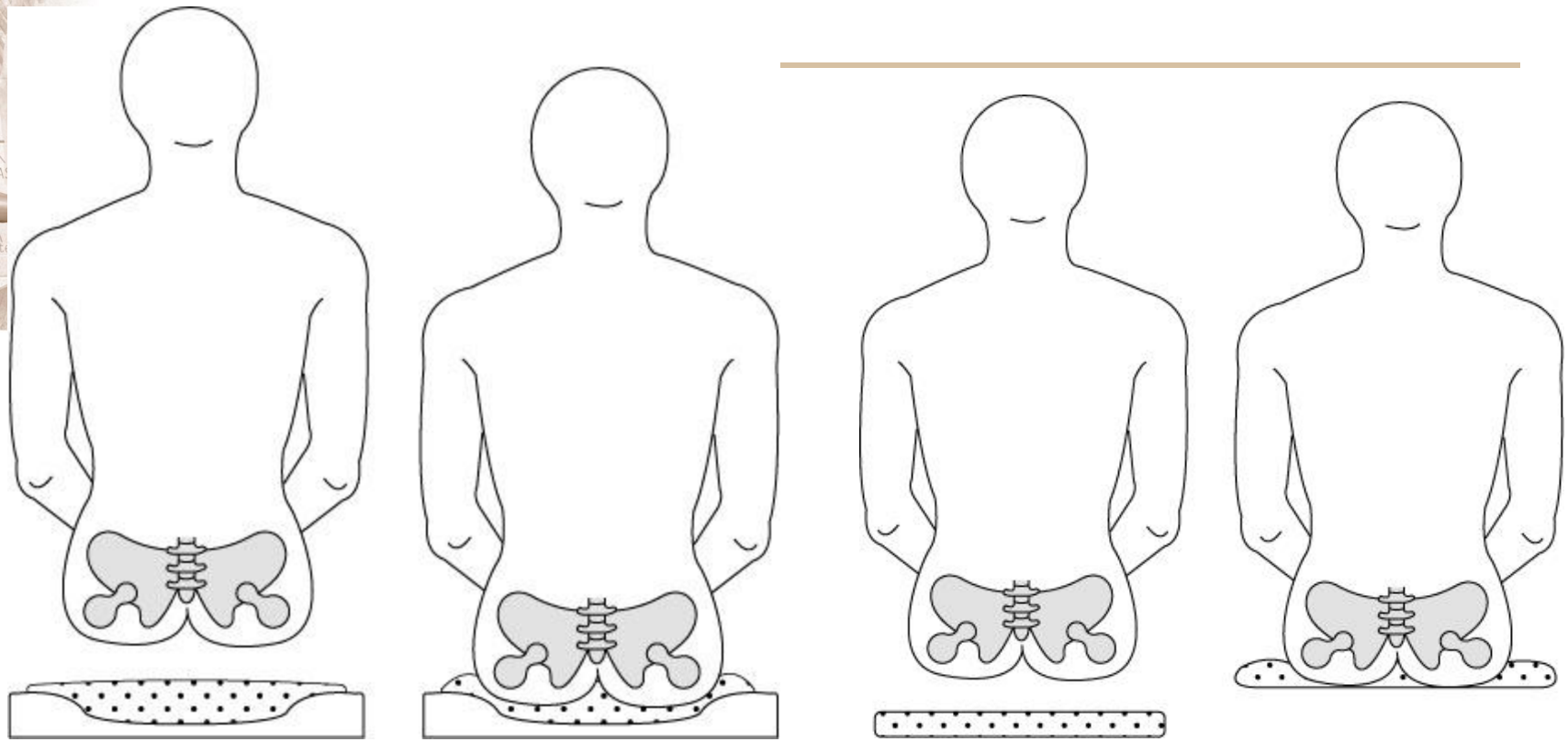


Foam: compression



Sitting on foam induces compression bending, tension of material
Segmented foam is functionally softer- reduced surface tension
(foam does not like to stretch)
Trick is to find foam that compresses just enough (40-60 IFD is typical for 3”)
Foam gets softer over time (fatigue)- look for tears, compression set

Viscous Fluid

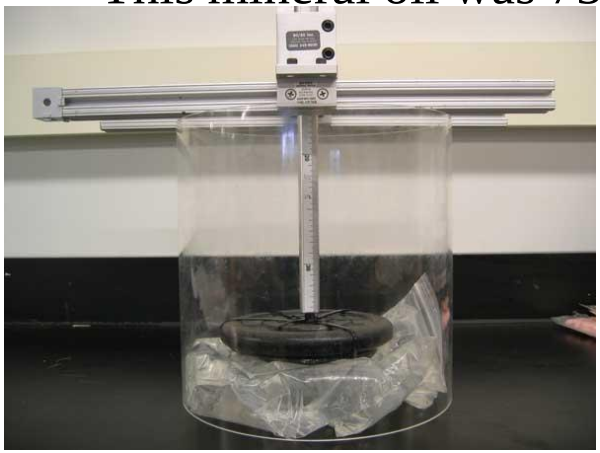


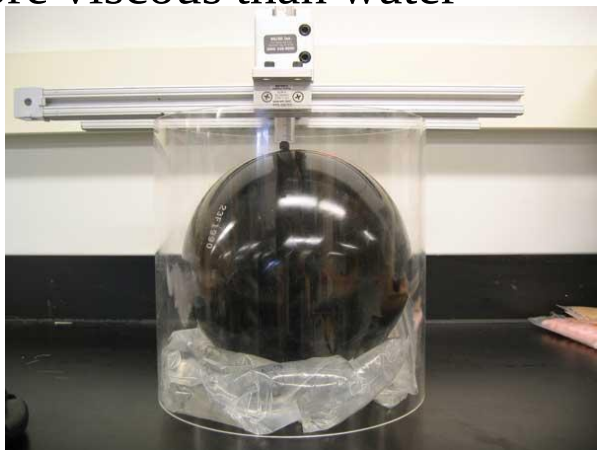
Requires proper base, bladder and volume of fluid
Best viscous fluid cushions are combination cushions (bladder alone would not be good)
Concept: allow fluid to flow and contain buttocks
Volume of fluid impacts immersion, not viscosity

Viscous Fluid: volume not viscosity matters

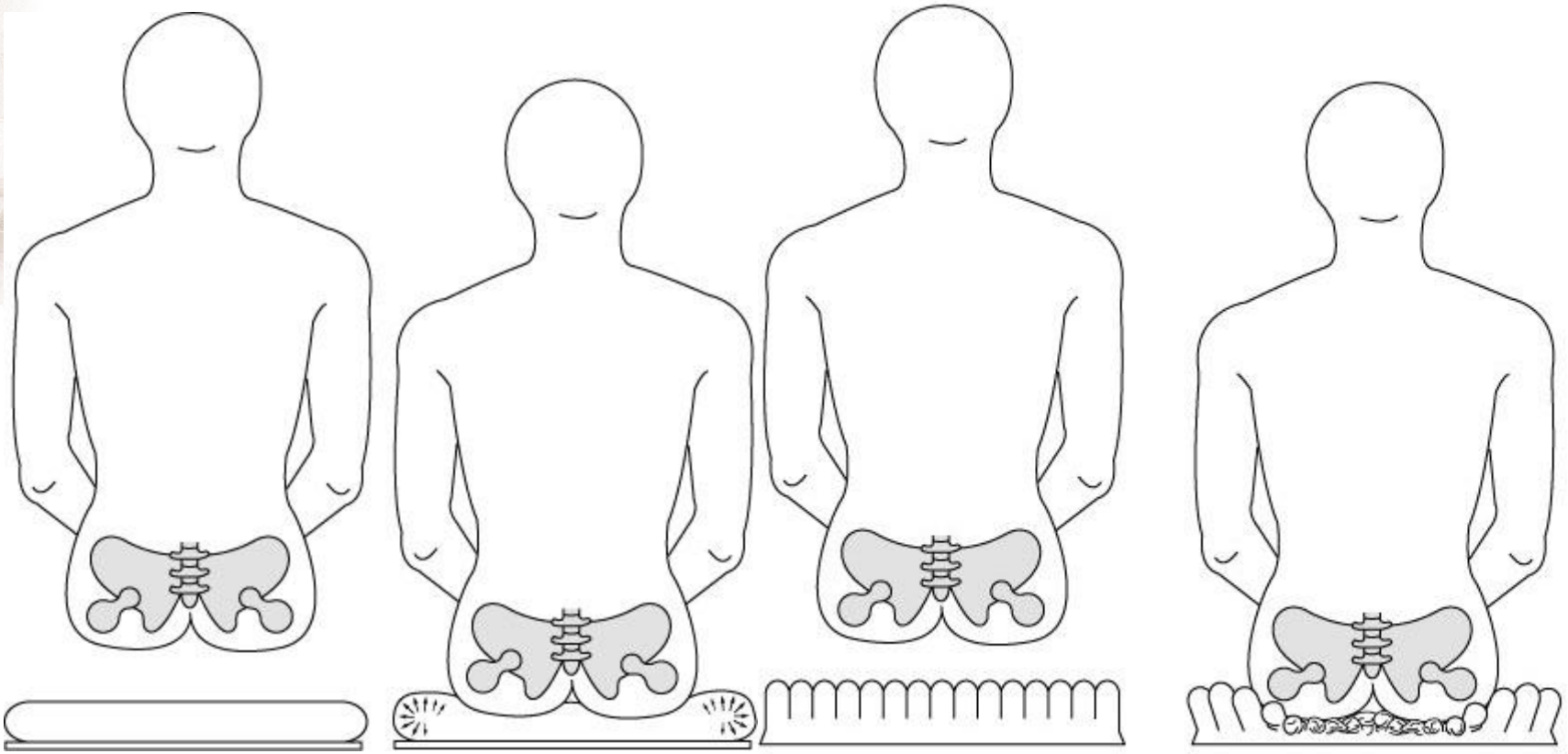
	Beveled Indentor	12 lb Bowling Ball
High viscosity Mineral Oil		
200 ml x 10 bags	2.3	2.8
150 ml x 10 bags	1.8	1.7
WATER		
200 ml x 10 bags	2.4	3
150 ml x 10 bags	1.6	1.8

This mineral oil was 75x more viscous than water





Air: container and volume matters



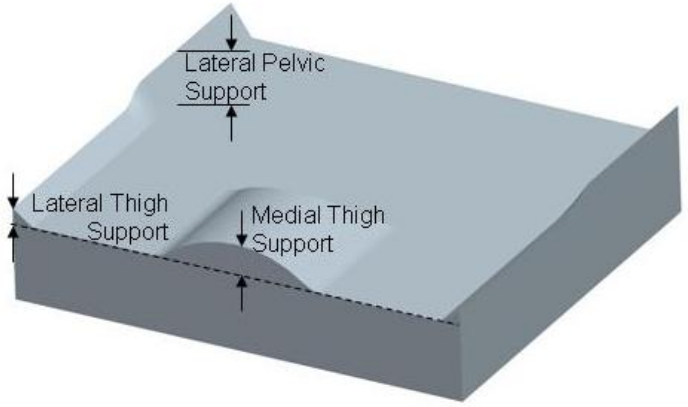
Single bladder system
Single air pressure
Envelopment highly bladder dependent

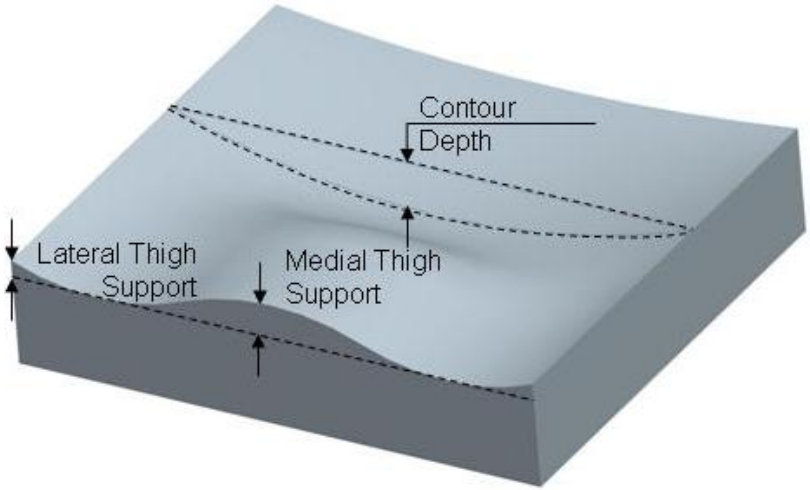
Multi-segmented bladders
Single air pressure
Segment collapse and expansion

All adjustable cushions require assessment
Over-inflation risk

Contoured and Positioning cushions

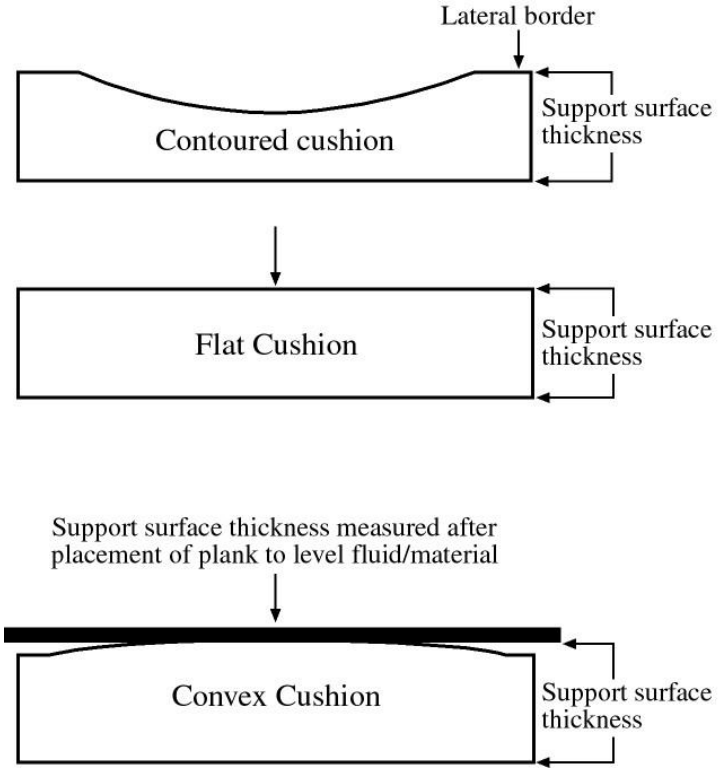
- "Positioning" can mean correction, accommodation, alignment or stability
- Contour depth helps determine *site specificity* and maybe something about *transferring* and *positioning*
  - The more complex the features, the more site-specific the fit
  - The more aggressive the support, the greater the potential impact on positioning and transferring
- Simple height and depth measurements may be descriptive but do not reflect performance
  - How high is high enough?
  - How deep a contour is enough?

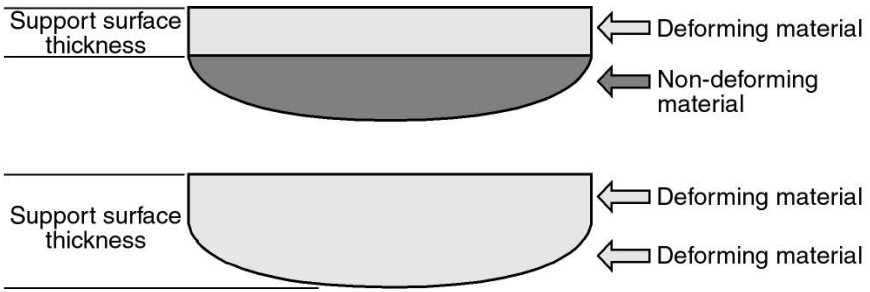




Support Surface v. Overall Thickness

- Thickness of a cushion has clinical relevance
  - And measurement of contour depth must also report thickness
- Supporting material must be distinguished from non-support material
- Certain cushions must be measured in different manners





Contouring impacts stiffness

- Flat cushions must deform to reach the final shape of the buttock-cushion interface
- Contoured cushions are closer to the final buttock-cushion interface shape

In Clinic, How can we use this knowledge?

- What style of product do we choose?
- How much maintenance and adjustment is required for it to function consistently over time?

In Clinic, How can we use this knowledge?

- Foam might be the perfect solution…
  - What's the life expectancy of this foam?
  - What happens if the clients shape changes?
  - What happens if the foam breaks down and changes the shape relationship?
- Consider how long it’s required to last
- What changes are predicted to occur with the client

Maybe Fluid is the choice…

- Do I have the right amount of viscous fluid?
- When tried – is the client “in it, or on top of it?
- When using air, can the client do the required maintenance consistently?

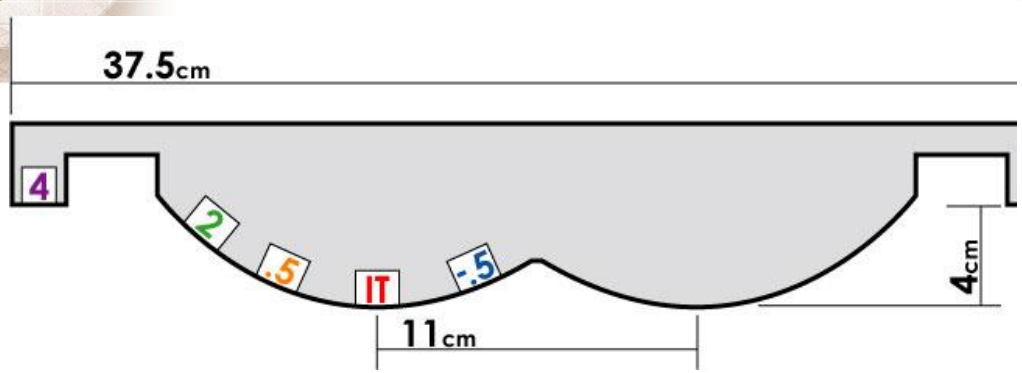
Load redistribution

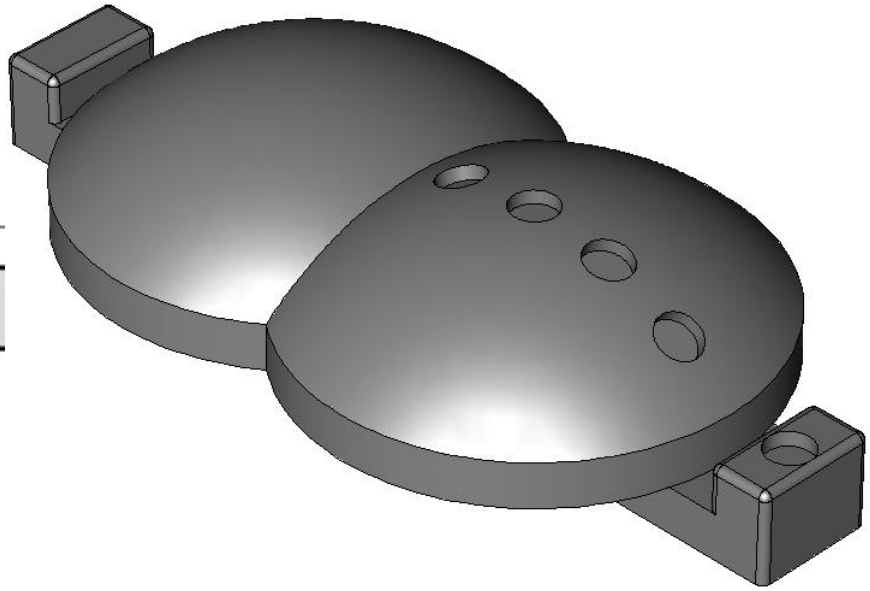
- The ability of a cushion to manage loads on the buttock tissues impacts tissue health and comfort
- Techniques used include:
  - Envelopment
  - Redirection of forces (including off-loading)

Envelopment

- Capability of a support surface in deforming around and encompassing the contour of the human body.
- An enveloping cushion should have the ability to encompass and equalize pressure about irregularities in contour due to buttock shape, objects in pockets, clothing, etc.

Envelopment & Off-loading: how we measure it





Parity: how equal are the 3 most inferior values; 0 means parity

Magnitude: sum of 3 most inferior values

Redirection of forces & off-loading

- Choosing where to apply loads on the body is commonly used in prosthetics and orthotics
- Several cushion designs use this approach to reduce ischial loading
  - Isch-Dish; Ride Designs
  - Contoured systems
  - Any system with ‘reliefs’ in a region

Envelopment measures

Values closer to 0 reflect best envelopment

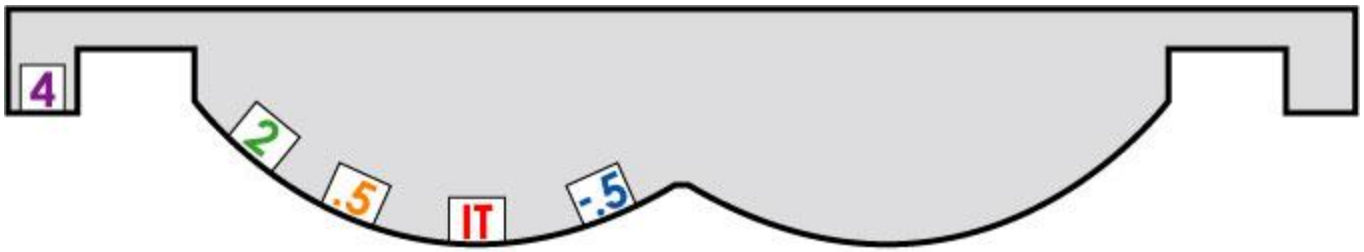
	Envelopment Parity
Reference flat HR45	0.44
Air & foam	0.07
Cellular matrix	0.06
convoluted foam	0.20
viscoelastic foam	0.20
segmented air	0.08
viscous fluid & countoured foam	0.02

Envelopment + Magnitude

	Envelopment		Magnitude	
	Parity			Mag IT Load
Reference flat HR45	0.44			323
Air & foam	0.07	similar	not similar	267
Cellular matrix	0.06			174
convoluted foam	0.20	similar	not similar	242
viscoelastic foam	0.20			168
segmented air	0.08			127
viscous fluid & countoured foam	0.02			128

Characterizing Load Distributing Performance

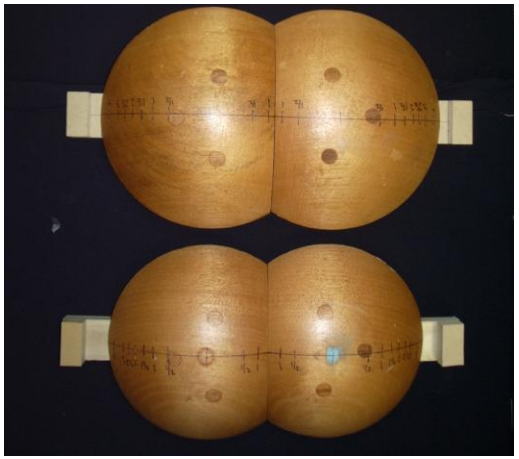
- One value is not enough
  - Magnitude
  - Envelopment
  - Immersion

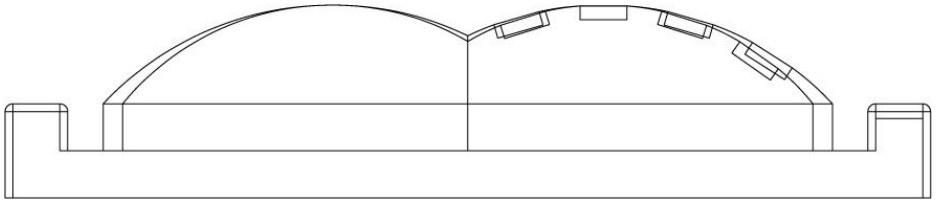


Characterizing Adjustability

- Measuring the ability to adjust to different types and sizes of people
  - 2 weights
  - 2 models
  - Comparison to flat foam

	56 Kg	84 Kg
Std model		
Peaked model		





In Clinic, How do we use this knowledge?

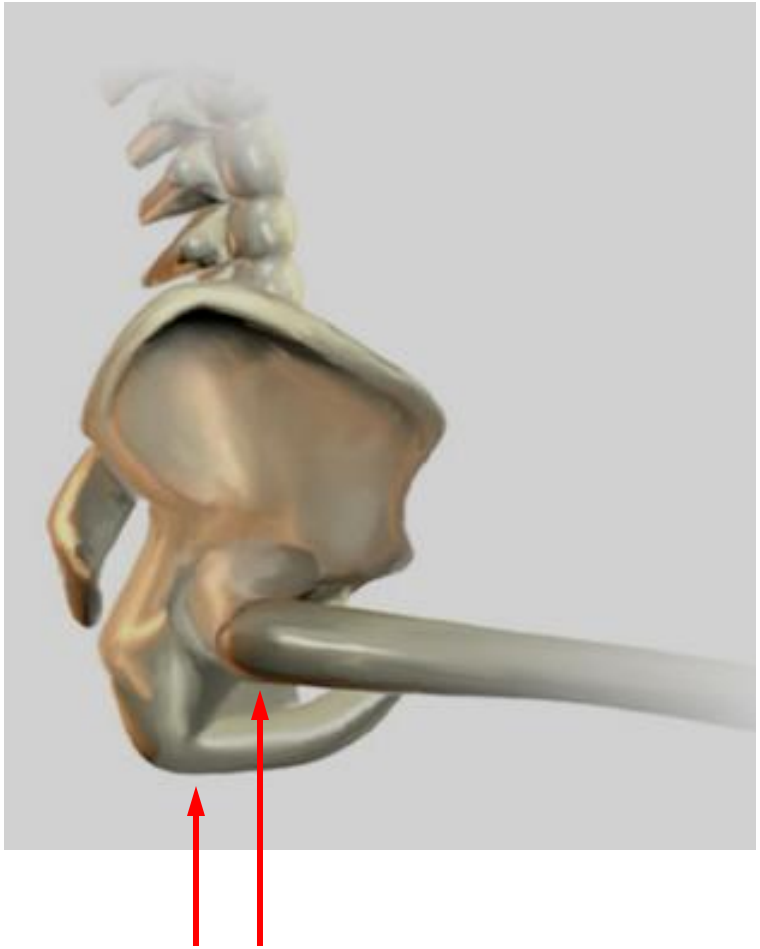
- Immersion
- Envelopment
- Magnitude

Immersion

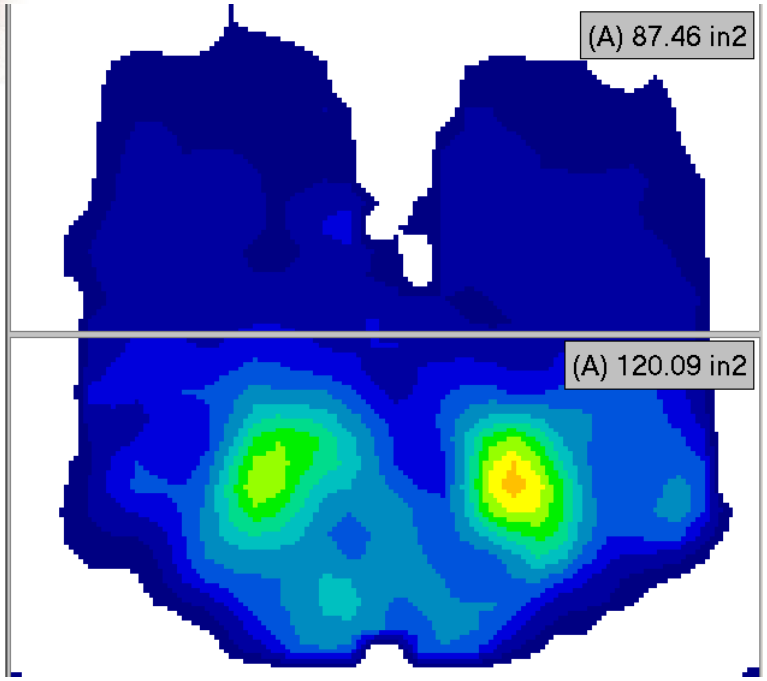
- How far does the client sink in?
- Tools we have to determine this…
  - Visual inspection of how much the pelvis, thighs and trochanters are immersed into the cushion
  - Pressure Mapping
    - Surface contact area

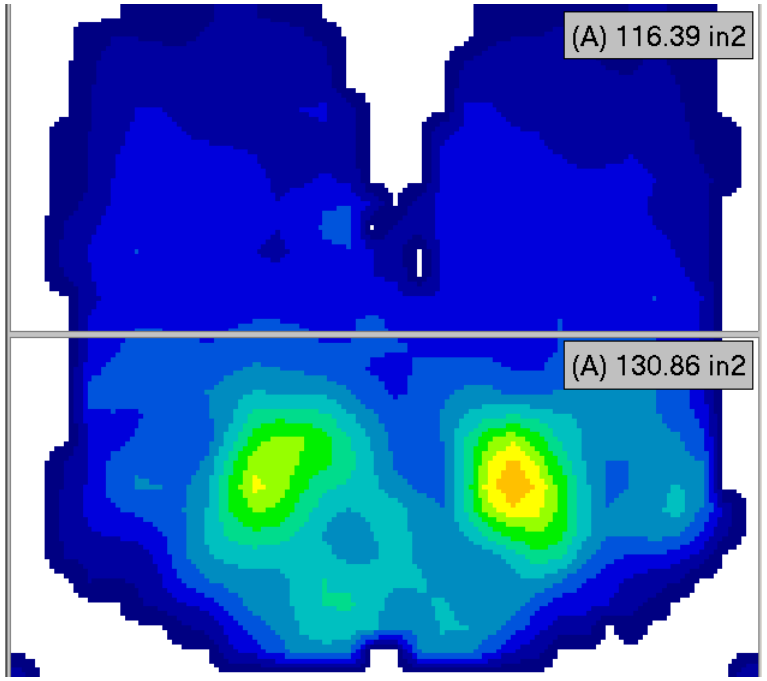
How much does the pelvis sink in?

- Palpation and visual inspection
- Remember the ischials in a bony person need to be able to immerse approx 2” without bottoming out




ASIS
Greater Trochanter


(A) 87.46 in2
(A) 120.09 in2

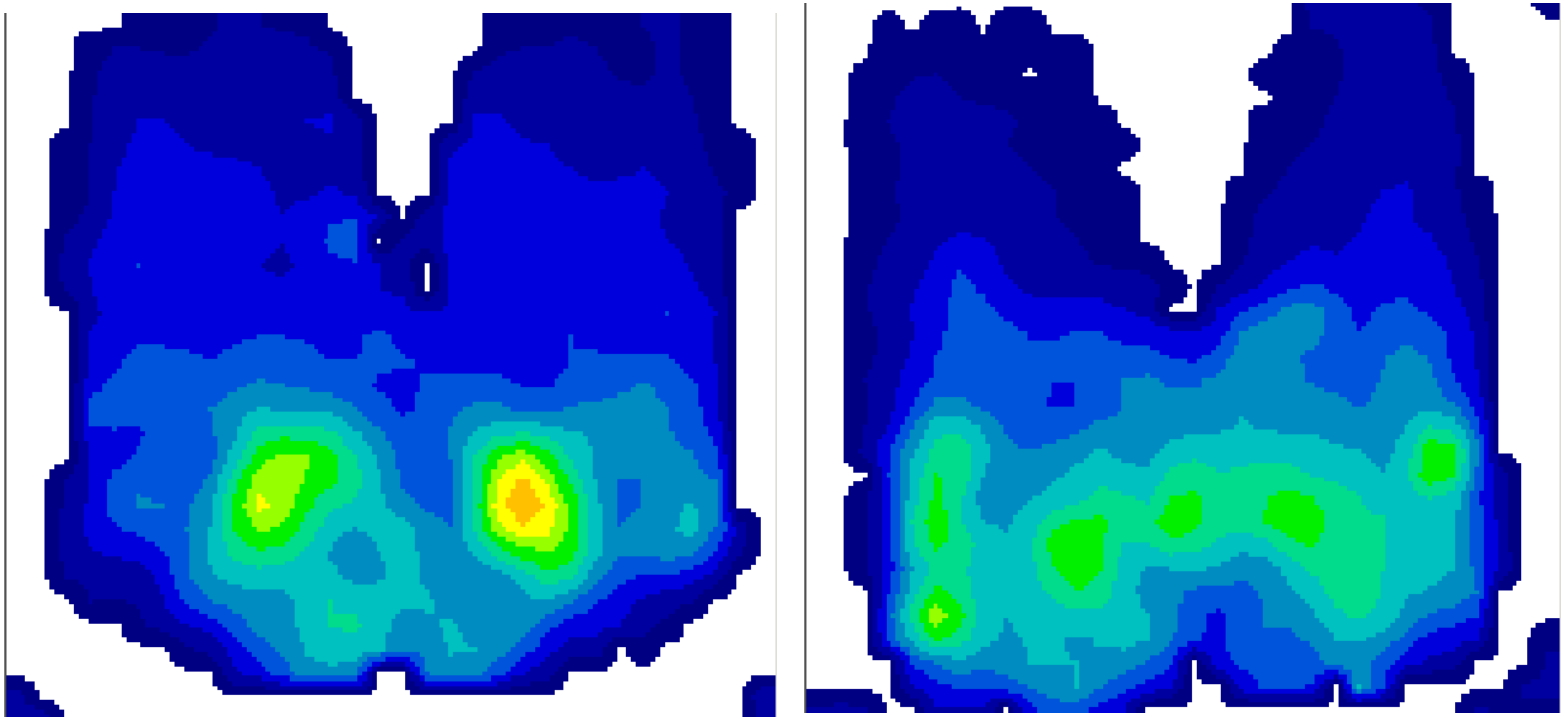

(A) 116.39 in2
(A) 130.86 in2

Envelopment

- How intimate is the shape formed with the clients shape?

- What tools have we to determine this?
  - Hands and eyes – Difficult……
  - Pressure Mapping
    - Color distribution and gradient


ASIS
Greater Trochanter



How much does this matter when …..

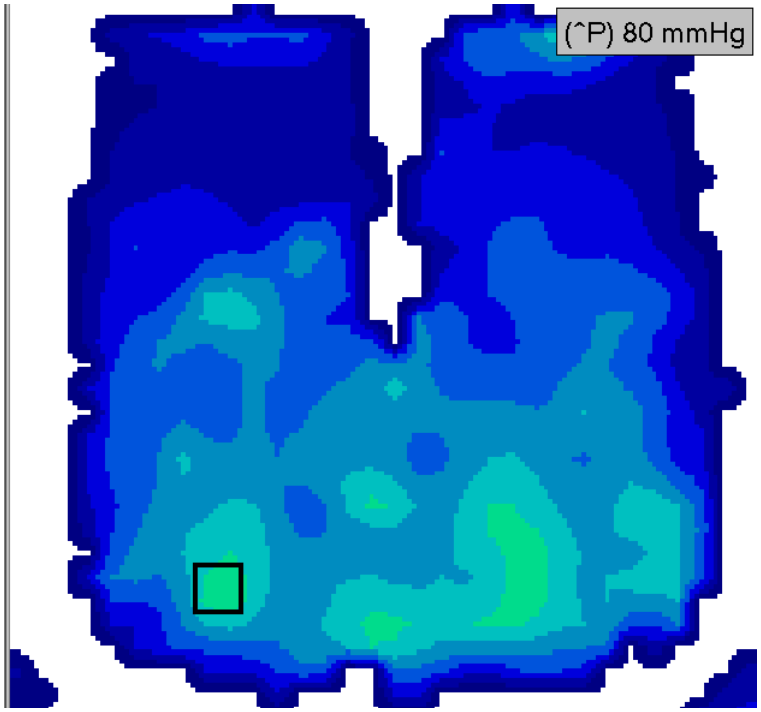
…Anything that interferes with the conformation is placed over top of the conforming material?

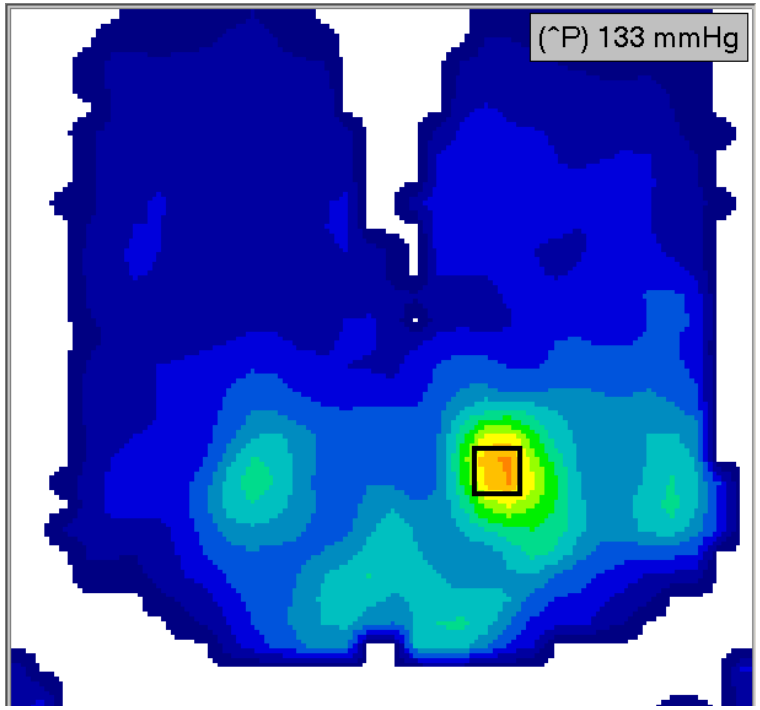
- Chuck pads
- Slings
- Diapers
- The list goes on…..!!!!

Magnitude

- How well has the cushion distributed the pressure
- The goal is usually to decrease the pressures on the IT's and spread to areas that can take load
- Tools to determine this…
  - Pressure Mapping
  - Where are the risk sites and how high is the pressure there?


ASIS
Greater Trochanter


(^P) 80 mmHg


(^P) 133 mmHg

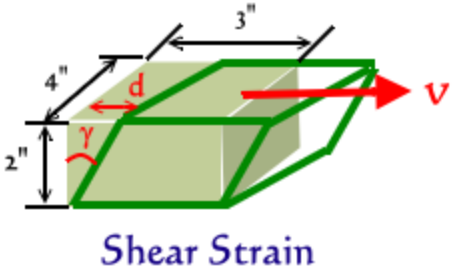
Redirection of forces

- Choosing where to apply loads on the body
- Generally we try to
  - load the areas tolerant of load
    e.g. the posterior thigh, feet and thorax
  - redirect load from areas less tolerant,
    e.g. the ischials, sacrum

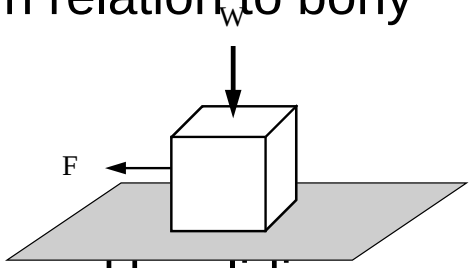
The BIG Questions –

- Can the client tolerate load for long periods of time on these areas?
- Does the client **consistently** get put into this shape that has been created for them
- If they need to move – can they?

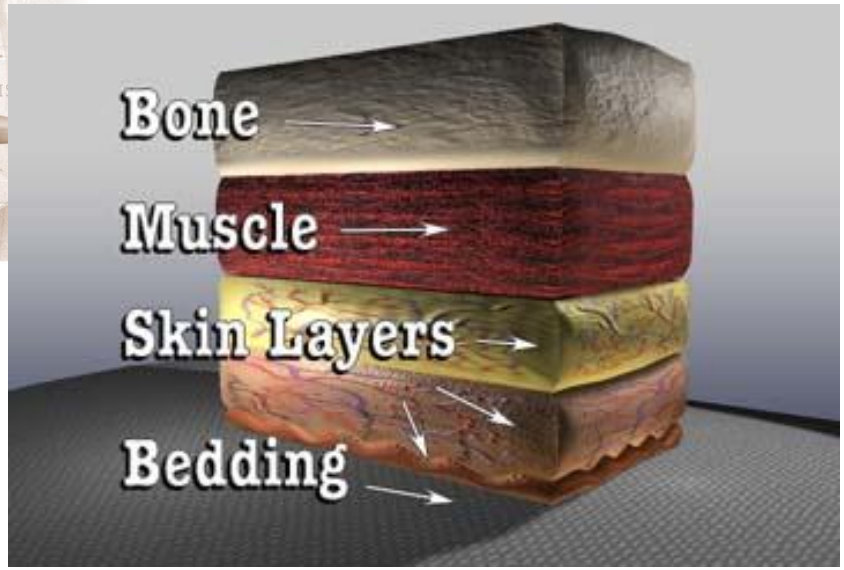
Shear and friction

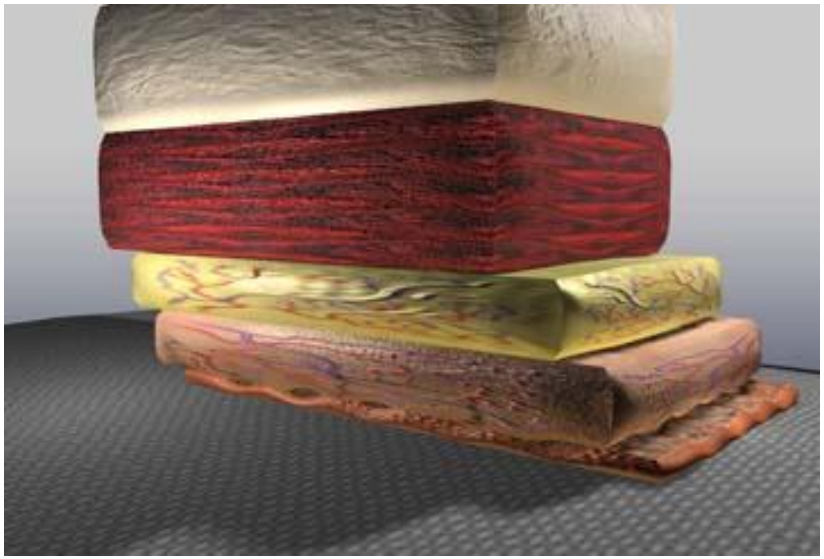


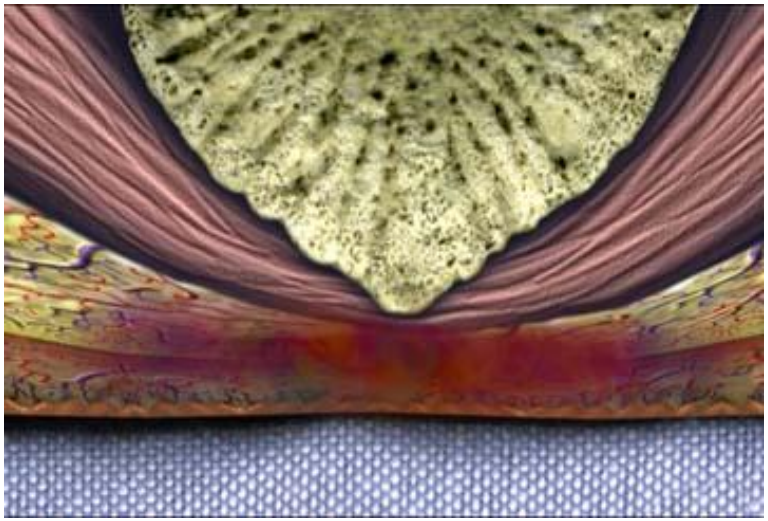
- Shear
  - Actually, *shear strain*- movement of tissues in relation to bony structures; tissue deformation
- Friction:
  - contact force that impedes sliding
  - clinically, often refers to damaging forces caused by sliding
  - frictional forces are proportional to normal forces
- Friction is a type of shear force, but not all shear forces are friction
- ALL forces on tissue (normal, friction, shear) induce shear strain in tissue
  - Any interaction causing tissue deformation will induce strain



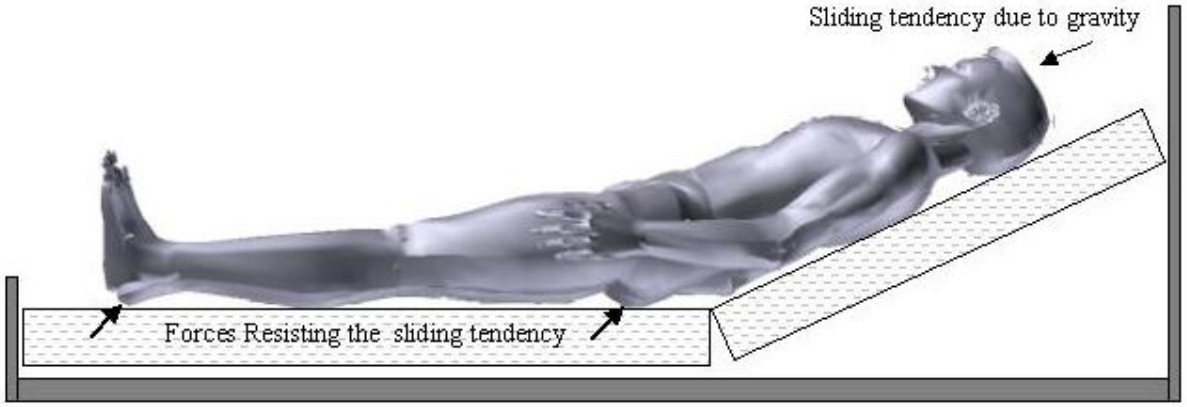
Shear strain in tissues



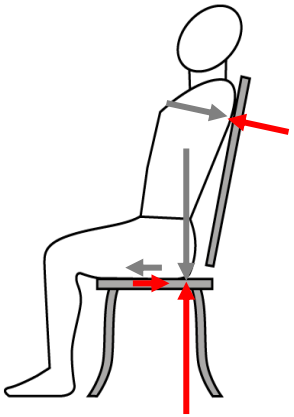




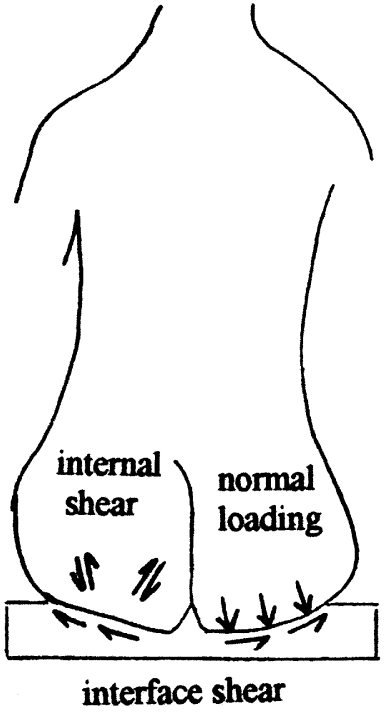
Friction and Shear



Frictional forces due to semi-recumbent position

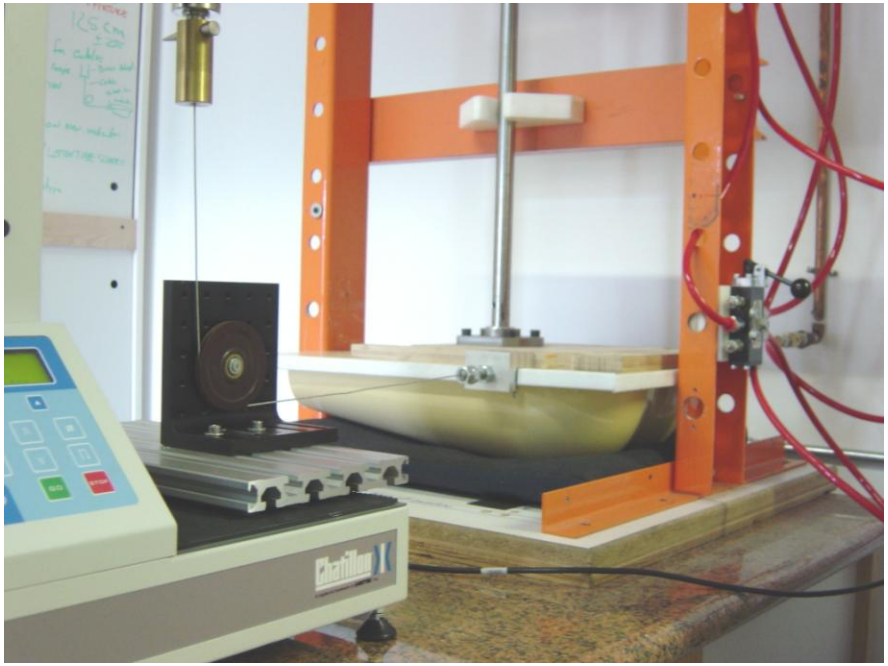


Anytime a backrest is used, friction must exist to keep a person seated



Horizontal Stiffness

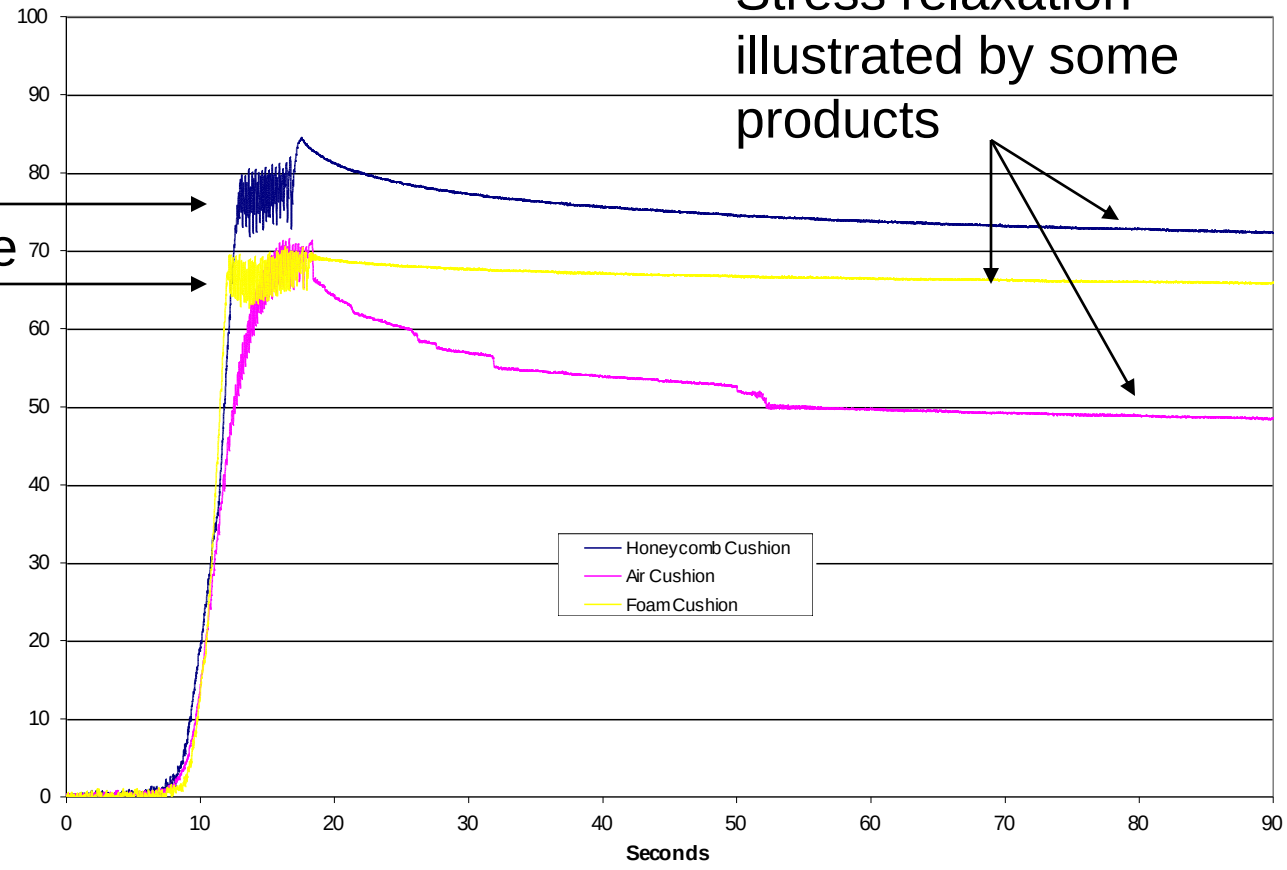
Sliding Resistance



Horizontal Stiffness Data

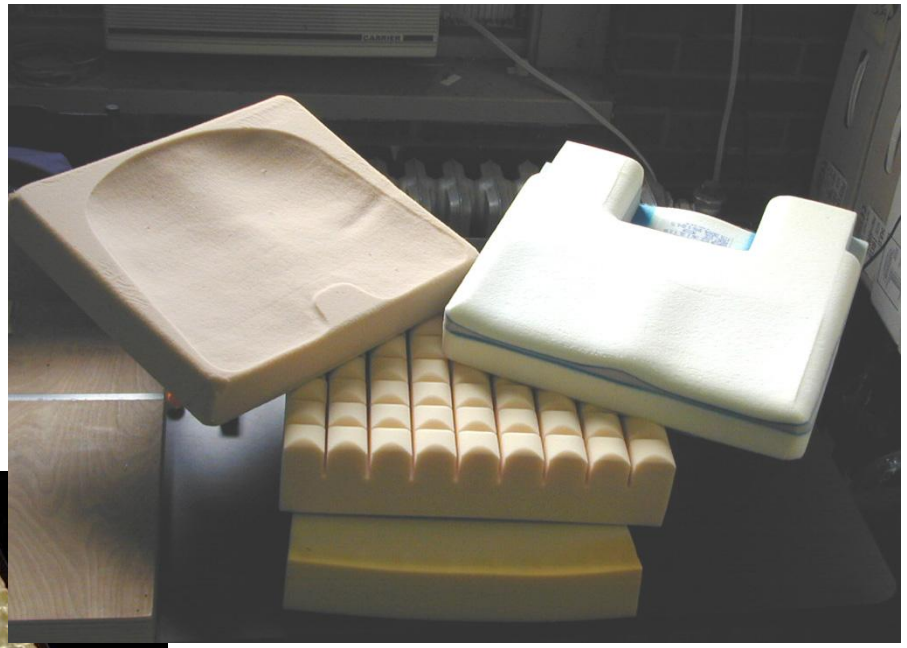
Height shows force required to slide

Stress relaxation illustrated by some products



Horizontal Stiffness

High Horizontal Stiffness



Low Horizontal Stiffness

Cushion impact on Posture & Reach

Sprigle, et. al, 2002

- SCI subjects
- Forward & lateral reach; uni- and bilateral
- 3 cushions
  - Roho HP
  - Jay 2
  - Varilite evolution
- No differences in reach or posture across subjects
- Subjects did reach and sit better on a particular cushion

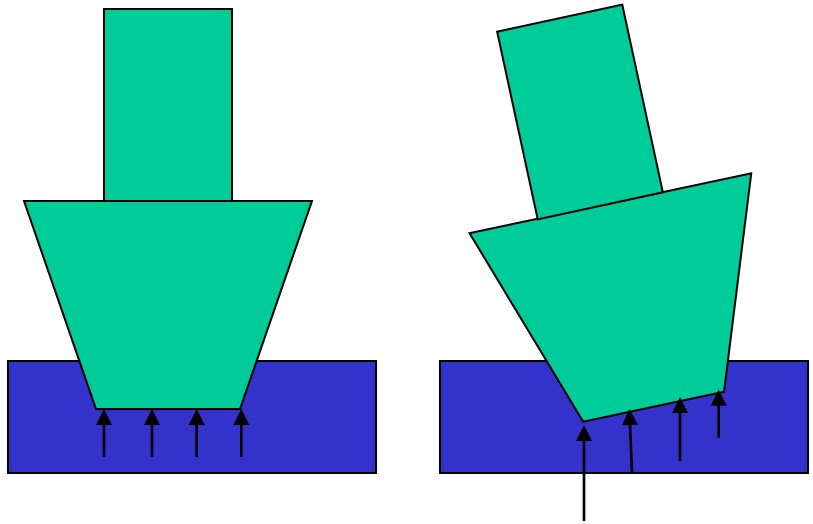
How does this impact tissue integrity & function

- Friction is ever present
  - Required to keep one in the cushion
  - Too much can hinder transfer and adversely impact tissue
- Some cushions are harder to slide upon
  - May help with positioning but hinder transfers
- “Functional Stability” reflects design and strategy

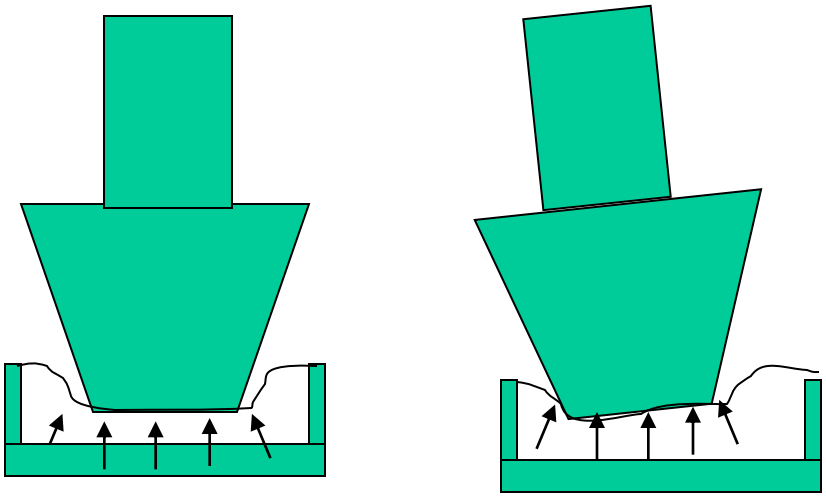
Resilience & recovery

- Ability to return to original dimensions after a deforming force is removed
  - Recovery relates to a slower process
  - Resilience reflects a more rapid response
- Ability to absorb energy
  - Impact and vibration

Resilience during lean

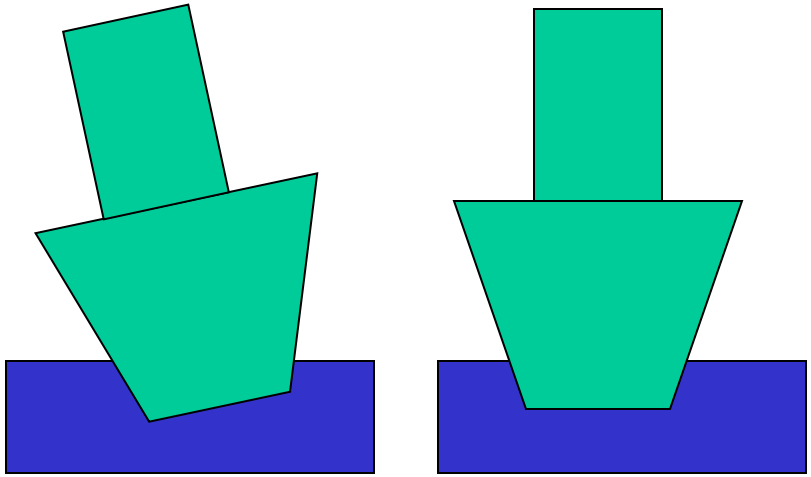


Resilient material-
↑ compression leads
To ↑ reactive forces
(like a spring)

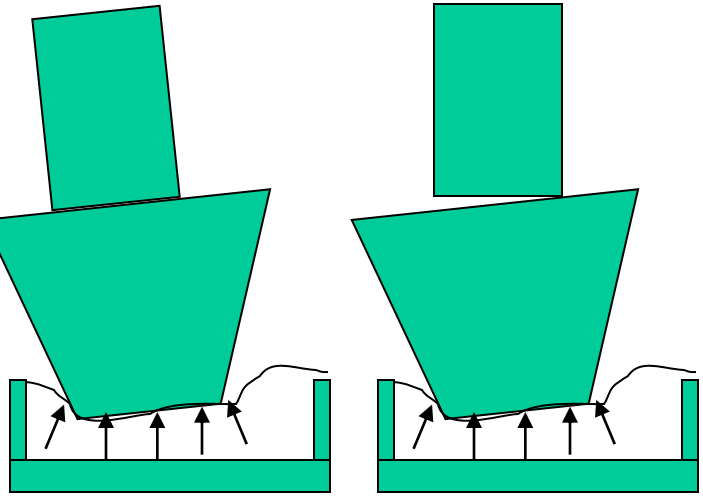


Stress relaxation
allows nonresilient
materials to relax
when deformed

Recovery- during & after a lean



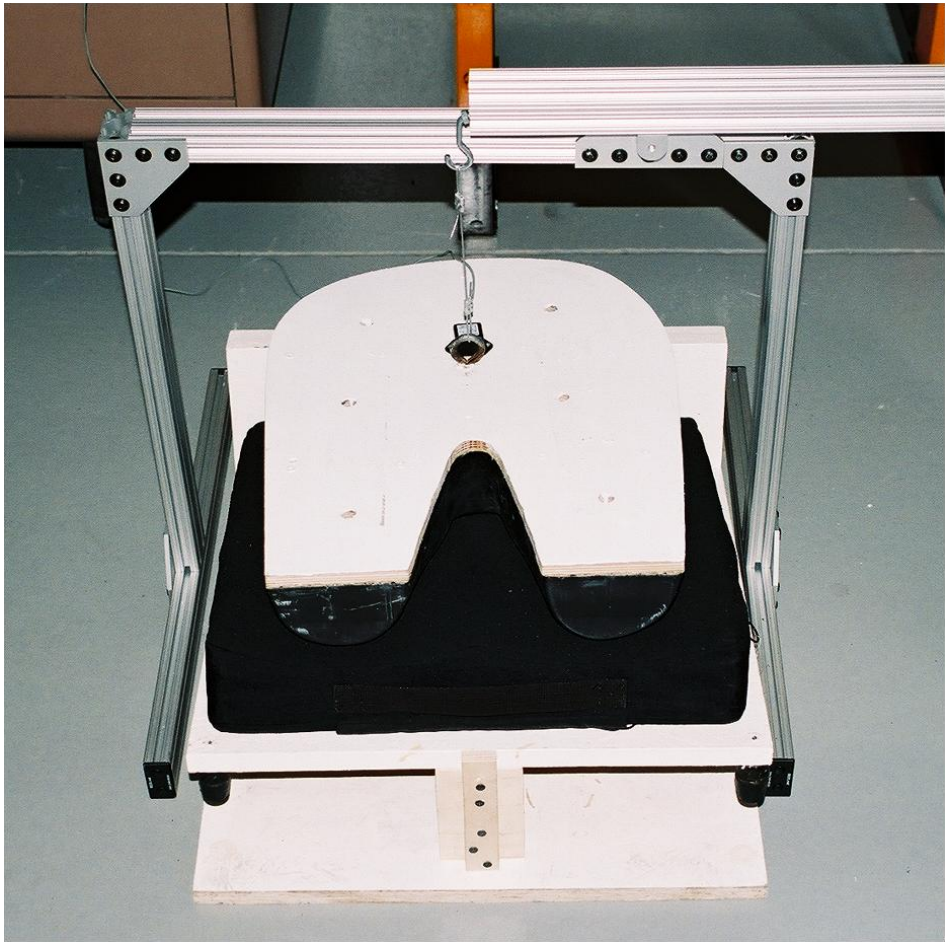
Resilient material- Resets itself after deformation



Non resilient material- Responds to loads and does not reset automatically

Impact Dampening

A measure of resilience & ability to absorb accelerations during everyday mobility

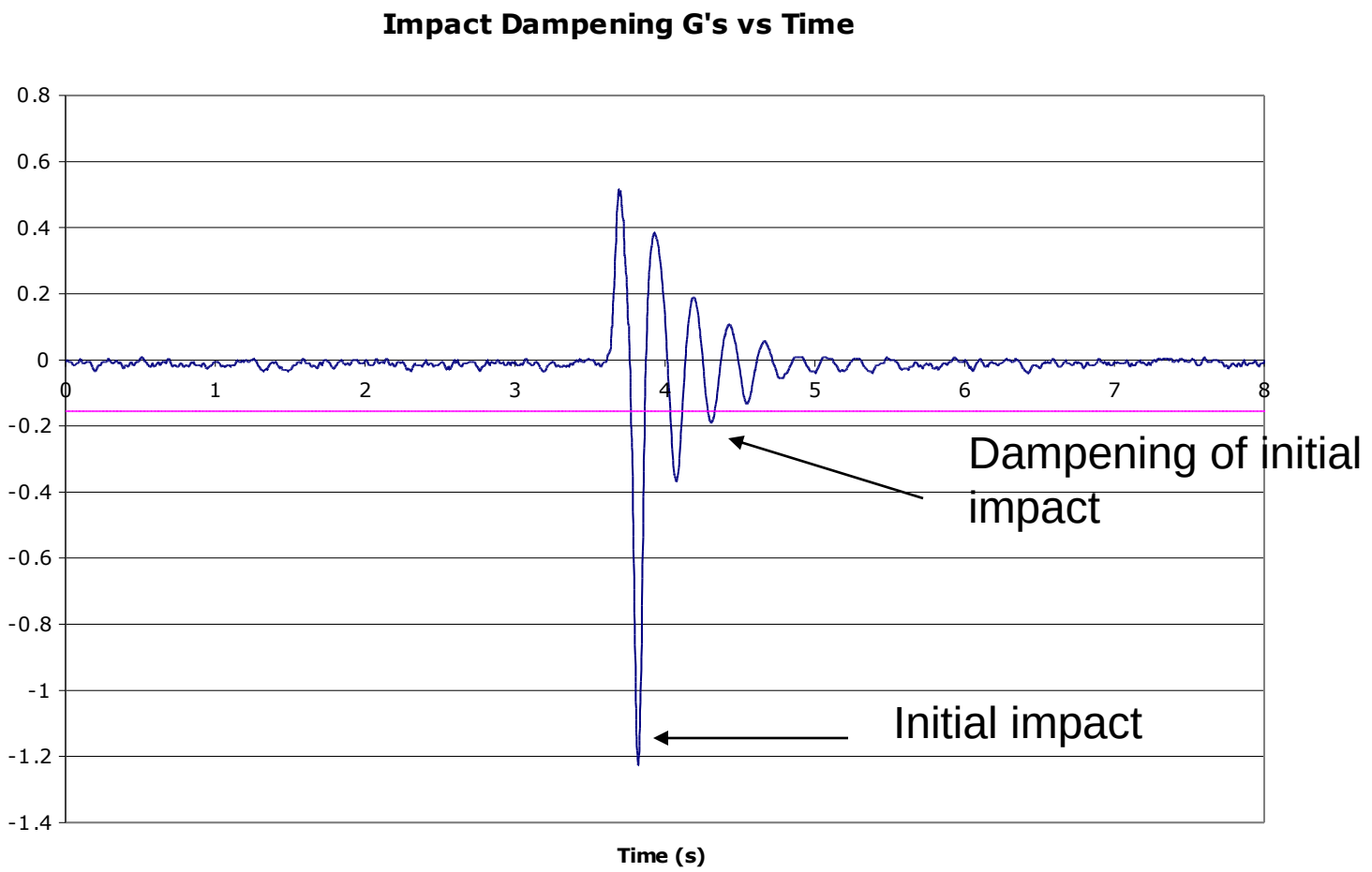


Impact Dampening

- Accelerations seen by the body
  - Vibration exposure
  - Force (F=mA)

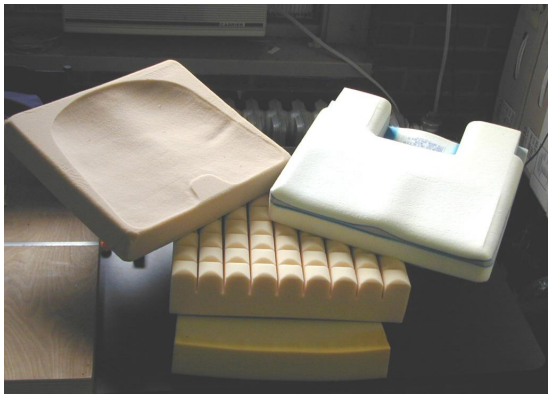
Impact Dampening Test

45 ILD Foam

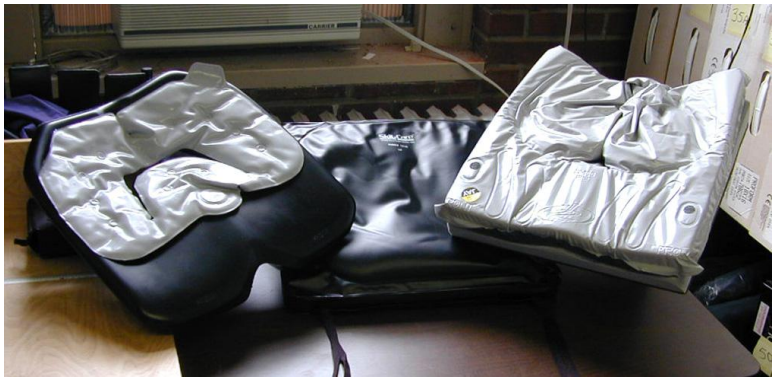


Impact Dampening

Low Impact Transmission



Higher Impact Transmission



Accelerations in everyday mobility

- Accelerations influenced by
  - Speed
  - Surface
  - Wheelchair design and configuration
- Everyday wheelchair usage
  - Most travel <1 mile
- Over everyday barriers, cushion does not have a significant influence on accelerations
  - DiGiovanne, et. al, 2003
- Impact dampening may be important for a select number of users
- Cushion is only one of several influences

Temperature, Humidity, Friction
3 Friends

Friction and Moisture

- As moisture increases, friction increases
  - ↑ softness → ↑ contact between surfaces
- Excessive moisture weakens skin's ability to withstand load

Segueing from moisture to temperature

- Linked via perspiration
  - ↑ skin temp induces perspiration
  - Obviously other sources of moisture

Temperature and it's impact on tissue viability

- ↑ tissue temperature ↑ metabolic demand
  - Added demand coupled with reduced nutrient delivery leaves tissues vulnerable
- Evidence suggests that reduced temperature has protective influence
  - Kokate (1995)
  - Patel (1999)
- Kokate: "At a given pressure, … lower temperatures exert a significant protective influence with respect to the development of pressure ulcers"

Temperature and pressure

- Lachenbruch (2005)
  - 2nd analysis of published data
  - 8ºC decrease in skin temperature is equivalent to a 29% reduction in interface pressure
  - Rightly advocates attention to skin temperature

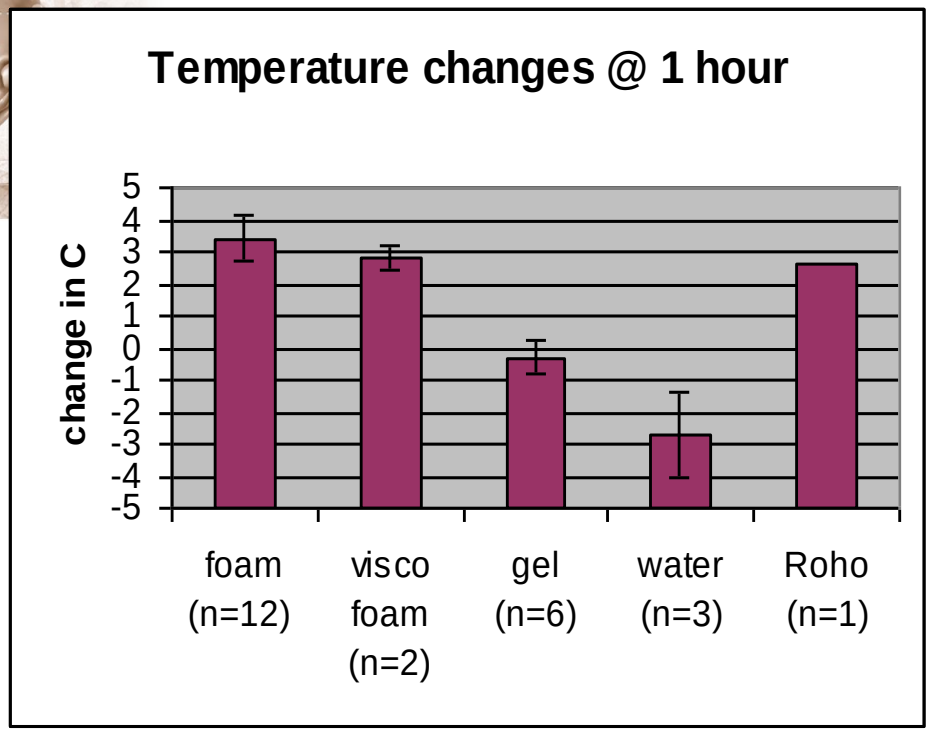
Heat: Insulators & Conductors

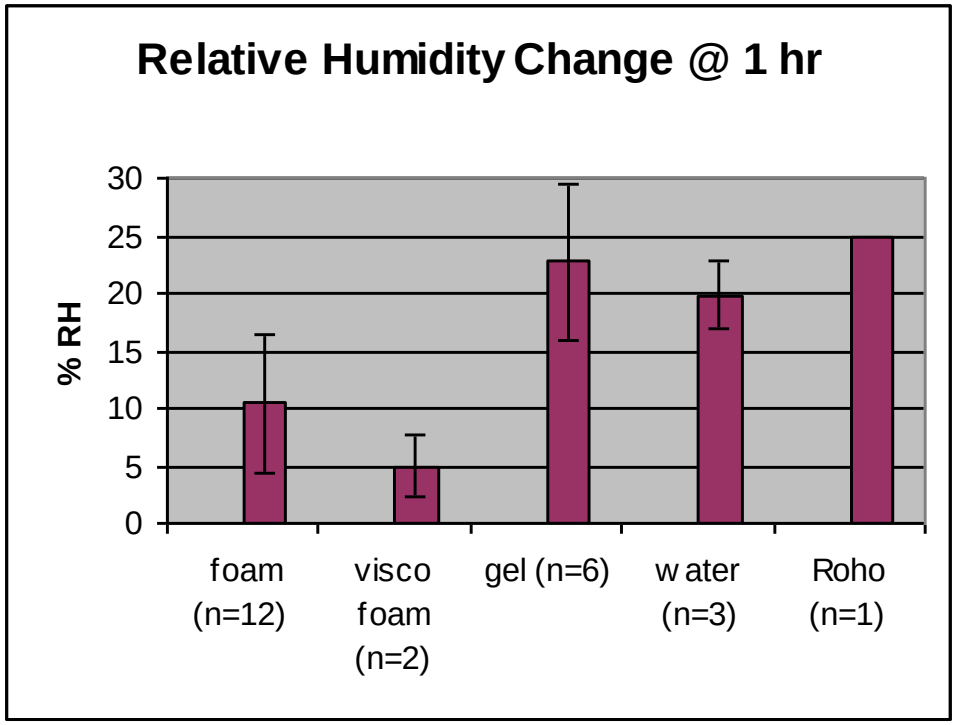
- Foam is an insulator
- Water is a good heat conductor

Low Thermal Mass

High Thermal Mass

Temperature & Humidity changes over 1 hour



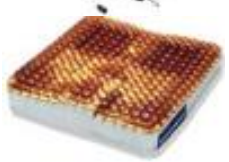


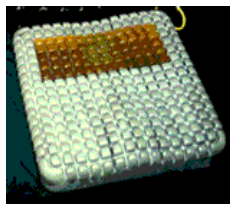
Foam & visco foam: warmer & drier
Gel & water: cooler & moister

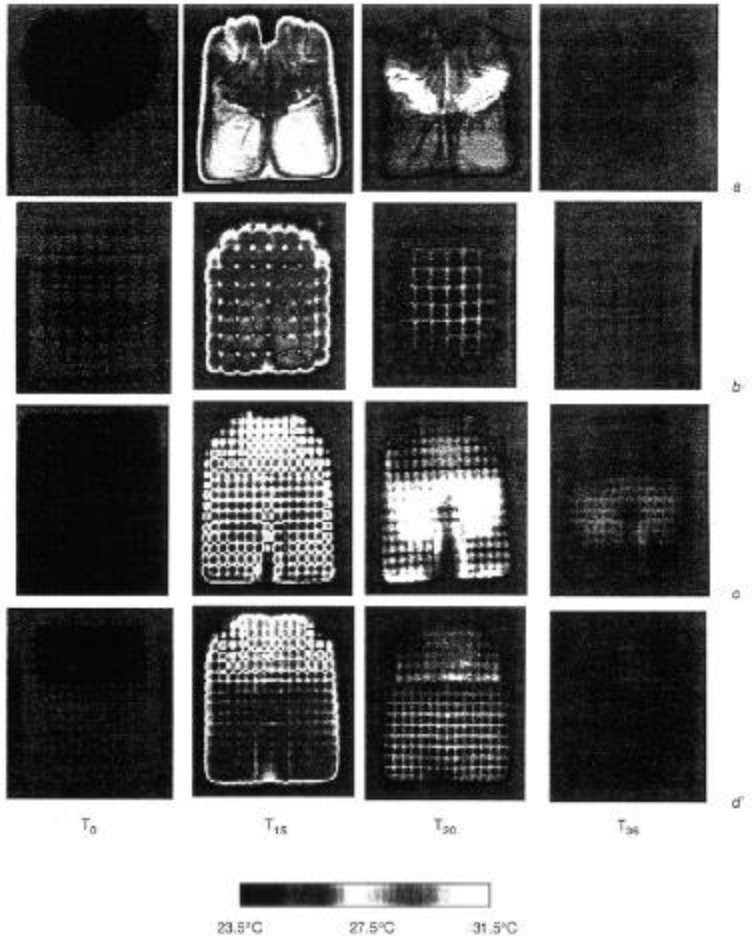
(Stewart, 1980)

Heating up and cooling down

- Sequence of images taken
  - Before sitting (T0)
  - After 15 of sitting (T15)
  - 5 & 15 minutes after transfer (T20 & T35)



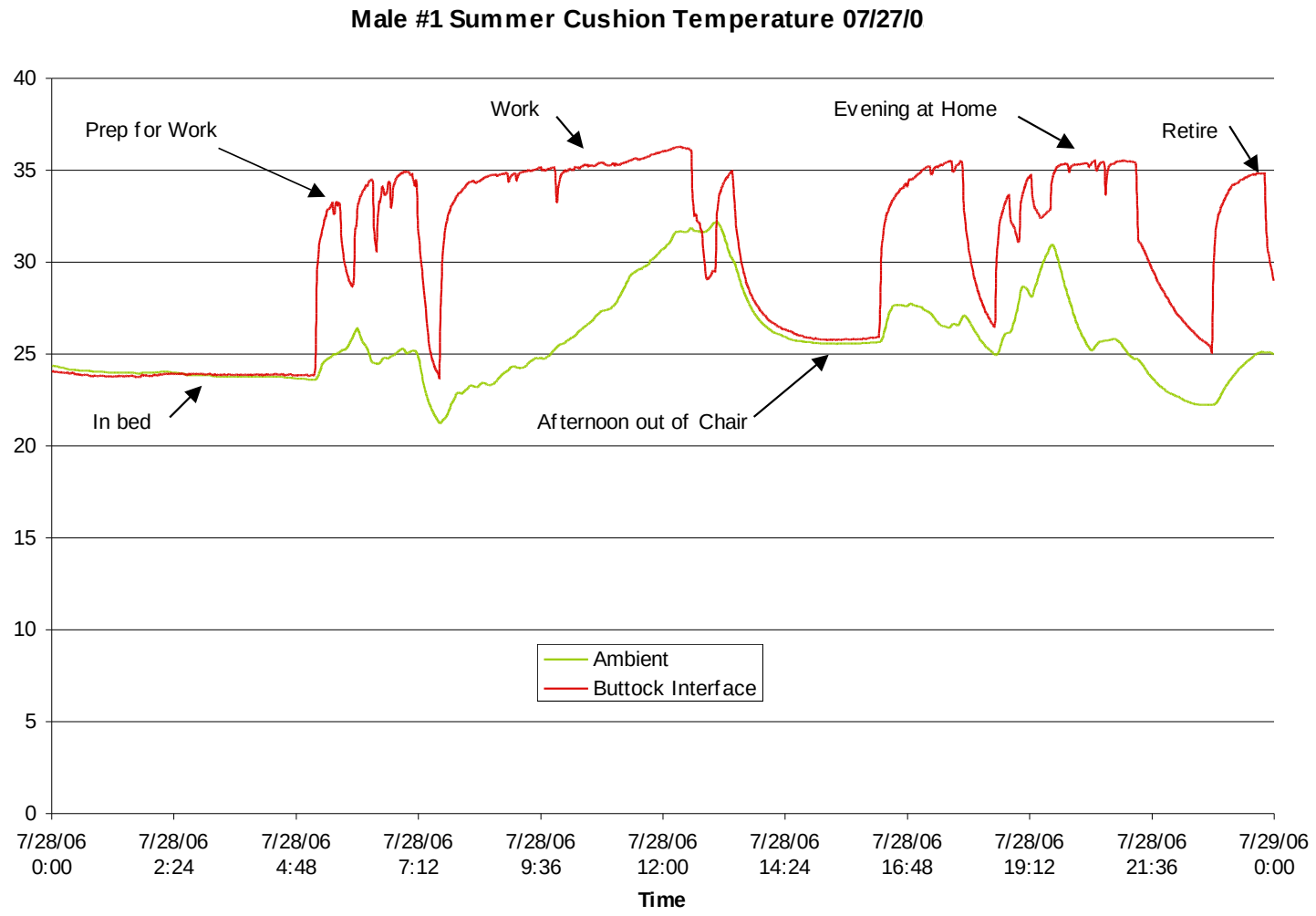




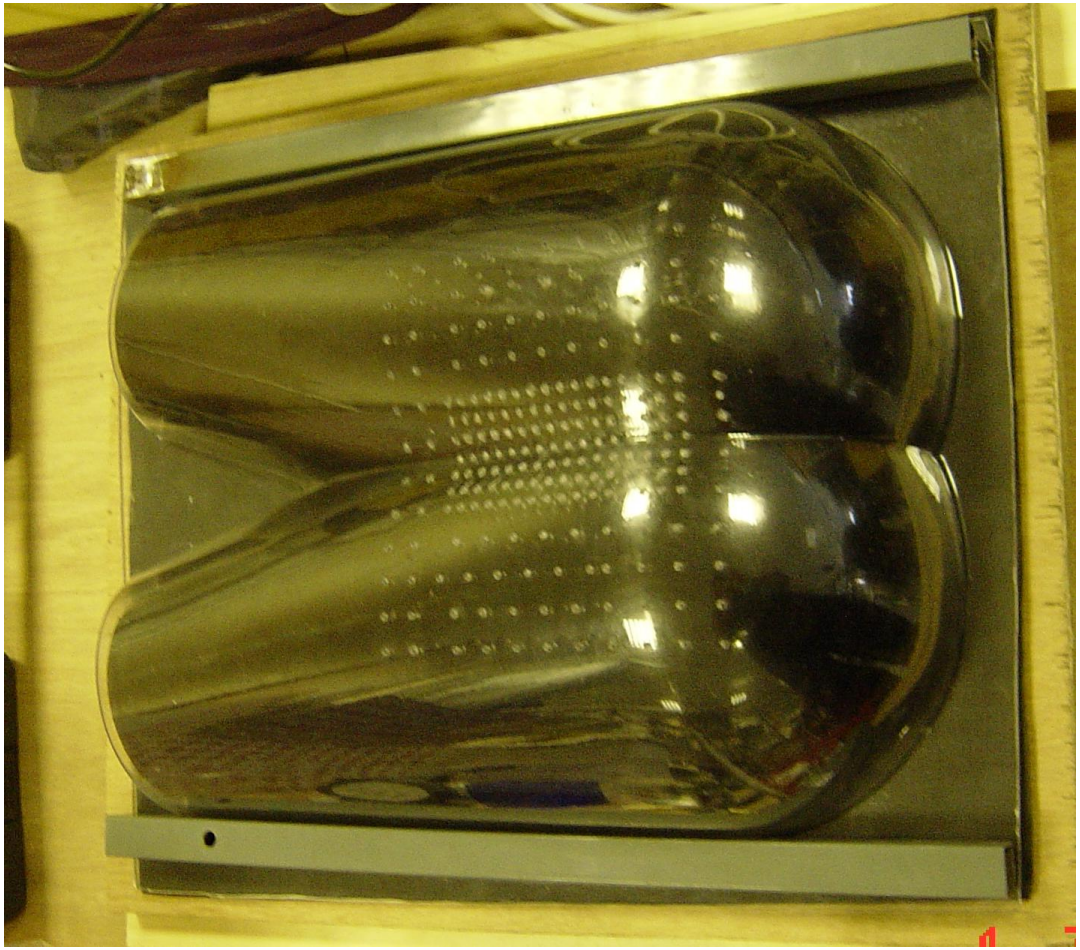
Cushions that take a longer time to warm up, take a long time to cool down

Ferrarin & Ludwig, 2000

Logging Temp over 24 Hrs

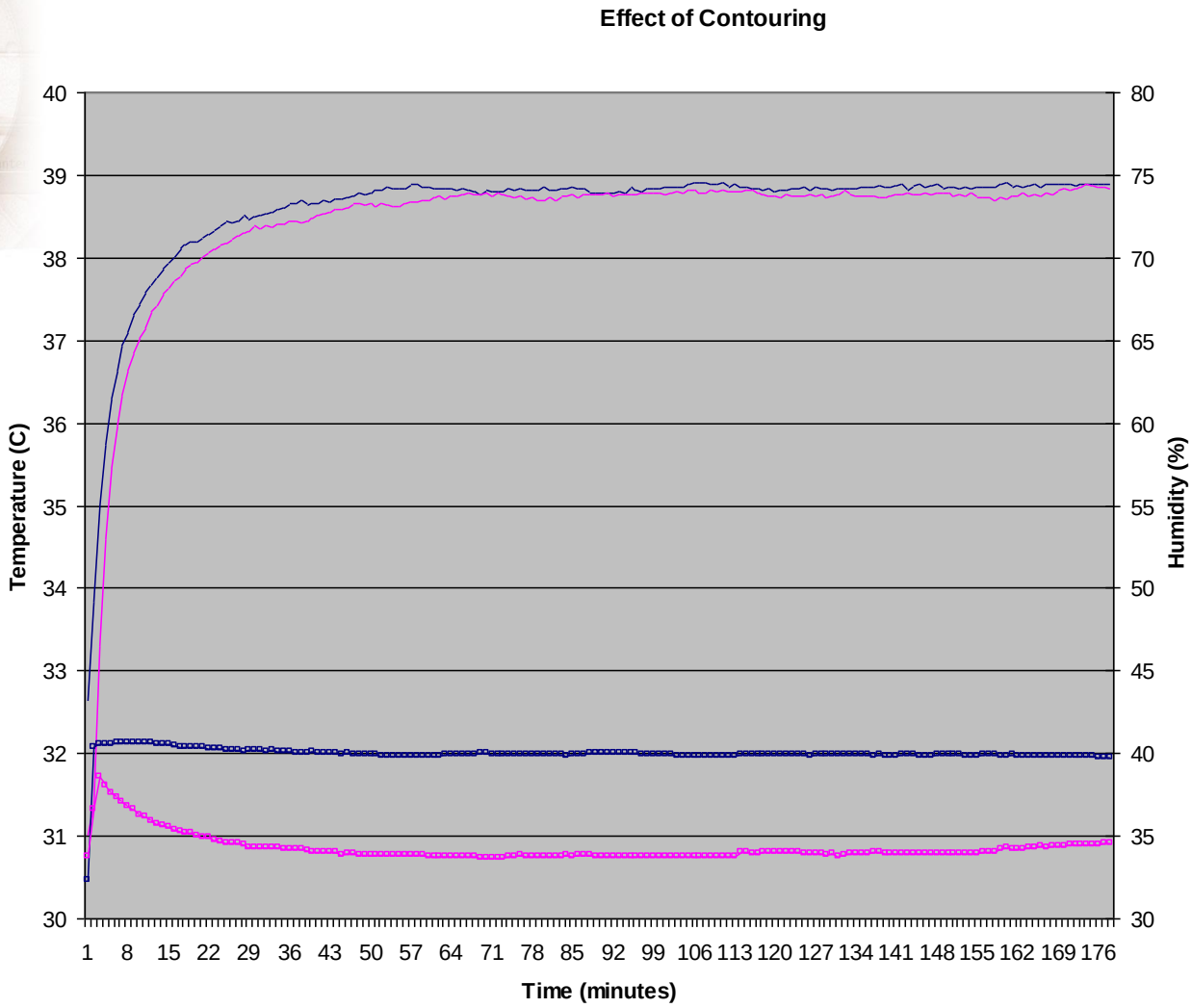


Heat and Water Vapor Test



Heat & Moisture Vapor Test

The effect of contouring



No difference in temperature

Contoured cushion offers lower humidity

What does all this mean to you?

- Put patients/clients into postures in which they can do stuff
  - Movement unweights tissue so dissipates heat & alters normal and shear loading
    - Body handles dynamic loading better than static
- Support surfaces that cause sweating need to be re-evaluated
    - Shear, friction and temperature implications
- Pressure reliefs have at least 2 purposes:
  - Alleviate pressure and dissipate heat

Heat and Water Thoughts..

- Is the cushion material an insulator or conductor of heat?
- What are the variables? – clothing – climate- etc
- Is the cushion moisture resistant with and without the cover?
- Is there moisture trapped around the skin surface?
- Incontinent covers – pads – diapers?

Heat…

- The slide tracking a 24 hour period reflects a key relationship between weight shifting and heat build up/ dissipation
- The more weight shifting that a person does, the greater the heat dissipation
- So, when a client is experiencing and reporting a lot of sweating discomfort the clinical responsibility is to educate and be aware of the impact of the selected materials

Heat…

- The better the cushion is for envelopment, Immersion and magnitude, the bigger the challenge it can be for heat and moisture issues
- Add incontinence to this
  - There is a greater need for increased frequency of weight shifting

Clinical Summary…

Immediately applicable take home messages

Load redistribution
•Envelopment
•Immersion
•Magnitude

Load deflection
•Stiffness

Heat & Water Vapor
Dissipation

Which Cushion to Choose?

- Think about level of stability needed
  - What happens when I move?
- Level of risk for skin issues
- Depth of immersion capabilities
  - Contact area provided?
- Envelopment
  - Even pretty colors….
- Magnitude
  - No red - ?? – remember – color means nothing
- How easy it is to customize?

Which one to choose?

- Can the client carry out all functional activities on the selected product
- IS IT COMFORTABLE? …For the client!!

Questions..

Thank You for Your Attention